Phys 128 - '98

1. Neutral hydrogen atoms in a gas discharge tube, originally in the ground state, are excited by collisions with free electrons with 12.9 eV of kinetic energy.

   (a) Calculate the longest wavelength and shortest wavelength photons that can subsequently be emitted by the hydrogen atoms.
   answer: 1876 nm, 97.3 nm

   (b) Find the maximum wavelength photons that will ionize the (excited) hydrogen atoms.
   answer: 1459 nm

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2. Two spaceships A and B have velocities measured by a stationary observer D as indicated in Figure 1.

   (a) Calculate the speed of spaceship B as measured by someone on spaceship A.
   answer: 0.960c

   (b) Determine the angle between the velocity of spaceship B and the line AD as measured by someone on spaceship A.
   answer: 15.9°

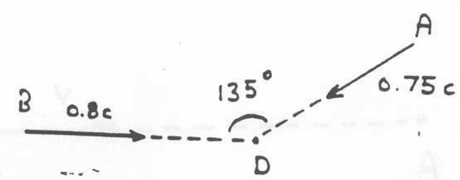

Figure 1: Velocities of spaceships measured by an inertial observer.

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3. A τ lepton, which has a mass of $1.78\,\text{GeV} = 1.78 \times 10^3\,\text{MeV}$, is observed to have relativistic kinetic energy which is 5 times its rest energy.

   (a) Find the magnitude of the relativistic momentum of the τ lepton.
   answer: 10.53 GeV/c

   (b) Determine the speed of the τ lepton.
   answer: 0.986c

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4. A mining ship leaves its base for an asteroid, 1.375 light years away, traveling at a speed of 0.8c. Light from this mining ship's departure is observed by the space patrol at its port, 0.170 light years from the asteroid, and 1.545 light years from the mining ship's base. The space patrol has a maximum speed of 0.99c, and the base, the port and the asteroid are all at rest.

   (a) After receiving the light from the mining ship's departure, how long can the space patrol wait before leaving the port if they wish to reach the asteroid before the miners?
   answer: 17.6 hr

   (b) Assuming that the space patrol travels at its maximum speed, how much time elapses for the space patrol on the trip to the asteroid?
   answer: 0.024 yr

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5. Incident photons with an energy of 579 MeV are Compton scattered from protons which are initially at rest. The scattered photons are detected at an angle $\theta = 36.5°$ with respect to the direct of the incident photons.

   (a) Calculate the energy of the scattered photons.
   answer: 516 MeV

   (b) Determine the emission angle of the scattered protons with respect to the incident photons.
   answer: 62.0°

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6. A Doppler radar system at rest at point A shown in Figure 2 emits electromagnetic waves with a frequency of 597 MHz as measured by an observer at rest with respect to A. The radar echo from B detected at A is 658 MHz.

   (a) Calculate the speed v of B as measured by A.
   answer: 0.0486c

   (b) Find the frequency of electromagnetic waves received by B.
   answer: 627 MHz

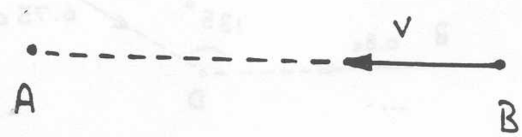

Figure 2: A Doppler radar system.

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7. What would the speed of an object, relative to an observer, have to be for its observed length to be contracted to one-fifth of its proper length?
   answer: β=0.980

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8. The radiation spectrum from the sun has its maximum intensity at a wavelength of 580 nm. The sun can be approximated as a blackbody radiator. The radius of the sun is 6.94×10^8 m.

   (a) Find the surface temperature of the sun.
   answer: 5,000 K

   (b) Determine the total power received from the sun by the Earth (distance from sun: 1.49×10^{11} m; Earth planetary radius: 6.37×10^6 m).
   answer: 9.80×10^{16} W

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9. Measurements are made of the photoelectric effect from copper. At a wavelength of 220 nm the maximum kinetic energy of the emitted photoelectrons is 1.07 eV while at a wavelength of 130 nm the maximum kinetic energy is 5.03 eV.

 (a) From these data determine a value for Planck's constant.
 answer: 4.19×10^{-15} $eV\cdot s$

 (b) From these data determine the work function of copper.
 answer: 4.65 eV

 (c) Using the value of Planck's constant from the data sheet, determine the maximum wavelength that would result in the emission of photoelectrons from the copper surface.
 answer: *267 nm*

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10. For the following isotopes, write out the decay reaction, calculate the disintegration energy, and determine whether the indicated decay mode can spontaneously occur.

 (a) ${}^{37}_{18}$Ar, atomic mass is 36.966772 u; positron emission (β^+ decay).
 answer: ${}^{37}_{18}\mathrm{Ar} \rightarrow \beta^+ + {}^{37}_{17}\mathrm{Cl} + \nu_e$; Q=-0.213 MeV; *no.*

 (b) ${}^{242}_{94}$Pu, atomic mass is 242.058710 u; α decay.
 answer: ${}^{242}_{94}\mathrm{Pb} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{238}_{92}\mathrm{U}$; Q=+4.95 MeV; *yes.*

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11. ^{14}C decays via β^- decay. The ratio of the number of ^{14}C to ^{12}C atoms in the atmosphere is approximately 1.3×10^{-12}. This ratio is the same as found in living organisms since they continually exchange CO_2 with the atmosphere. When an organism dies it no longer absorbs ^{14}C from the atmosphere and the amount of ^{14}C decreases with time.

 (a) What would be the activity (in Curies) of 1.50 g of carbon found in a living organism?
 answer: 1.01×10^{-11} *Ci*

 (b) If the ratio of ^{14}C to ^{12}C in a sample of carbon taken from a once-living organism is found to be 2.5×10^{-13}, determine how long ago (in years) the organism died.
 answer: 1.36×10^{4} *yr*

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12. A 100 cm^3 sample of sea-water contains 11.0 g of hydrogen. Of this hydrogen, only 0.0150% is deuterium.

 (a) Compute the energy that would be obtained if all the deuterium in the sample of sea-water were consumed in the ${}^2\mathrm{H} + {}^2\mathrm{H} \rightarrow {}^3\mathrm{H} + {}^1\mathrm{H}$ reaction.
 answer: 3.21×10^{8} $J = 2.00\times10^{21}$ MeV

 (b) What would be the energy released if two-thirds of the deuterium were fused to form ^{3}H (via the reaction listed in (a)) which was then fused with the remaining deuterium via the ${}^2\mathrm{H} + {}^3\mathrm{H} \rightarrow {}^4\mathrm{He} + n$ reaction?
 answer: 1.15×10^{9} $J = 7.15\times10^{21}$ MeV
